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TECHNICAL REPORT 88-1

ALTERNATE CURING STUDY FOR REINFORCED CONCRETE PIPE

FIRST INTERIM REPORT

FEBRUARY 1988

M.A.P. CODE 7.42-6-88-1

NEW YORK STATE DEPARTMENT OF TRANSPORTATION
MARIO M. CUOMO, Governor **FRANKLIN E. WHITE, Commissioner**

TECHNICAL REPORT 88-1

ALTERNATE CURING STUDY FOR REINFORCED CONCRETE PIPE

Prepared by

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February, 1988

MATERIALS BUREAU
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ABSTRACT

In the Fall of 1987, a joint study was initiated by the NYSDOT's Materials Bureau at the request of the NYS Concrete Pipe Association to determine if air curing of reinforced concrete pipe (RCP) is sufficient to produce an acceptable product. Both air cured and steam cured pipe were manufactured and tested for absorption, freeze-thaw and strength. Test results from this production showed acceptable values. This study will be continued during the Summer of 1988 to obtain test results for RCP produced in hot weather.

BACKGROUND

Most reinforced concrete pipe (RCP) used on New York State Department of Transportation contracts range in size from 12 inches to 42 inches in diameter. These sizes are normally machine made, the most popular process being the packerhead method. Usage of larger pipe is rare. Consequently, these units are usually wet cast.

Department specifications require that both machine made and wet cast pipe be cured, and then tested for strength and absorption prior to acceptance. (For specific details, the NYSDOT Standard Specifications are available from the Materials Bureau upon request.)

In an effort to become more competitive with other types of pipe, RCP producers have been looking at ways to reduce costs. One area investigated was curing, since steam curing is expensive and strength test results from properly made and cured pipe always seemed to be considerably higher than the specified requirements. This prompted the producers to conduct their own strength tests on pipes that were only air cured in enclosed areas where the ambient temperature was maintained at 50°F or higher for a minimum of 12 hours before testing. Results of these tests were encouraging, showing strengths comparable to those obtained with steam cured pipe.

In 1987, the technical committee of the New York State Concrete Pipe Association (NYSCPA) presented their test results to the Department's Materials Bureau and proposed that a joint study be conducted to confirm their findings and further demonstrate, to the Department, that air curing is sufficient to produce acceptable RCP. After reviewing the test data, the Materials Bureau agreed to participate in the proposed study, as favorable results would also benefit the Department (i.e. lower prices through competitive bidding on Department contracts). This report describes the study that ensued and the results obtained from tests conducted in the Fall of 1987. Further tests will be conducted during the summer of 1988 to determine the effects of hot weather air cure. Results from these tests will be reported at a later date.

INVESTIGATION

Participant Responsibility

Further discussions concerning the joint study defined the responsibilities of both the Materials Bureau and the participating RCP producers. These responsibilities are as follows;

	Materials Bureau		RCP Producers
(1)	Design the experiment	(1)	Manufacture and cure sample pipe at their facilities at no cost to the Department
(2)	Observe the manufacture of sample pipe and record mix design data	(2)	Provide mix design and curing data
(3)	Select sample pipe for strength and laboratory tests after curing	(3)	Core selected sample pipe for laboratory tests
(4)	Observe strength tests and record results	(4)	Conduct strength tests
(5)	Conduct laboratory tests for absorption and freeze-thaw	(5)	Collect weather data for 14 days after production
(6)	Report the results of the experiment		

Experiment Design

The experiment, designed for the study by the Materials Bureau, is entitled NYSDOT/NYSCPA ALTERNATE CURING STUDY FOR CONCRETE PIPE and is presented in the Appendix. For the most part, the procedures outlined in this experiment were followed. However, some minor modifications were made before the study began. These modifications were as follows;

(1) The RCP producers requested permission to wet cast 48 inch diameter sample pipe in 4 ft. lengths rather than in 8 ft., 7 ft. 6 in. or 6 ft. lengths. This request was approved, as it would have no bearing on test results.

(2) The RCP producers requested that the 48 inch diameter sample size (20) be reduced because of the time involved to wet cast this many pipe. Action on this request will be taken before testing resumes in the Summer of '88. All pipe produced for the Fall '87 tests were machine made.

(3) The RCP producers requested that laboratory tests be initiated and strength tests be conducted after 7 days rather than 14 days. The Bureau agreed to test at 7 days with the stipulation that tests would be repeated at 14 days.

(4) The RCP producers requested permission to remove rings from machine made pipe after 12 hours of curing rather than 16 hours. The Bureau agreed to this request if it could be demonstrated that it could be done without damaging the pipe.

(5) Both participants agreed that air curing be suspended during the months of November through March except on Long Island where air curing could continue during November and March.

Sample Pipe Production, Curing And Testing

During the months of September and October of 1987, three RCP producers manufactured pipe for the study. All used packerhead equipment. The producers, along with the sizes and numbers of pipe manufactured, were as follows;

Producer	Class III Pipe Dia. (Inches)	Number of Units
Boccard Industries Inc. Bayshore, NY	12	20
	24	20
	36	20
Bundy Concrete Products Inc. Watertown, NY	12	20
L. S. Lee & Son Oaks Corners, NY	12	20

Personnel from the Materials Bureau were present to observe sample pipe production, record cement factors (pounds/cubic yard), and select which pipe would be steam cured and air cured. To eliminate the possibility that test results would be influenced by batch variance, every other pipe made was chosen for steam cure. The remainder were air cured. Once made and set in separate curing bays within the plants, the outside forms were removed and the pipes were appropriately marked for identification. During the initial 12 hour cure period, temperatures were monitored with temperature recorders placed in the curing bays.

In some instances, the bays containing air cured pipe were left open on the ends, exposing the pipe to ambient temperatures. In other instances, the ends were closed off with burlap drapes which provided some protection from outside temperatures.

The following day, the rings were stripped from the pipes (attempts to remove rings at 12 hours has not, as yet, been attempted) and the pipes were moved from the curing bays to stockpile areas outside the buildings. Here Materials Bureau personnel randomly selected the pipes to be cored for laboratory tests and those to be subjected to strength tests. Three to five days after manufacture, the RCP producers cored selected pipe, under the supervision of Regional Materials personnel, and shipped the cores to the testing laboratory in Albany so that absorption and freeze-thaw tests could begin on the seventh day. The RCP producers then conducted the required strength tests on the seventh day. These tests were observed and results recorded by either Materials Bureau or Regional Materials personnel. This entire process was repeated a week later for fourteen day tests. During this two week period weather data was recorded by the RCP producers.

The data obtained during sample pipe production and curing, along with the results of subsequent laboratory and strength tests, are presented in the summary forms that follow.

Alternate Concrete Pipe Curing Test Results
N.Y.S.D.O.T. Materials Bureau

Company Name: Boccard Industries, Inc.
Location: 45 South 4th St., Bayshore, NY 11706

Production Date: 09/22/87 Pipe Diameter: 12 in. Cement Factor 750 #/cy
Forms Stripped 20.5 hrs. Actual Steel Area 0.10 sq.in.

Strength (psi)(7 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-4	Passed	45200
A-6	Passed	49200
A-9	Passed	54200
S-4	Passed	43700
S-8	Passed	48200
S-10	Passed	-----

Curing Conditions (First 7 Days)

Steam Temp. Range: - to - F.
Percent Rain: 7%
Humidity (%) Range: 58 to 88
Low Temp. Range: 48 to 61 avg. 56
High Temp. Range: 64 to 84 avg. 77

Strength (psi)(14 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-5	Passed	49200
S-2	Passed	51200

Curing Conditions (7-14 Days)

Percent Rain: 29%
Humidity (%) Range: 41 to 100
Low Temp. Range: 42 to 54 avg. 46
High Temp. Range: 59 to 68 avg. 64

Absorption: ASTM C497

*Sample #:	A-2	A-3	A-7	avg.	S-1	S-5	S-9	avg.
7 Day Core:	5.8	6.1	6.1	6.0	5.3	5.2	4.7	5.1
14 Day Core:	5.8	5.6	6.4	5.9	4.9	5.1	4.9	5.0

Freeze-Thaw Weight Loss (3% NaCl): NYSDOT 502-3P
25 Cycles - One Cycle per Day

*Sample #:	A-2	S-5
7 Day Core:	0.0	0.0
14 Day Core:	0.0	0.0

REMARKS:

* A designates air cure, S designates steam cure.

Strength Requirements - Class III:
0.01" Crack Load = 1350/Lin.Ft. x 8 Ft. Length, 10800
Ultimate = 2000/Lin.Ft. x 8 Ft. Length, 16000

Alternate Concrete Pipe Curing Test Results
N.Y.S.D.O.T. Materials Bureau

Company Name: Boccard Industries, Inc.
Location: 45 South 4th St., Bayshore, NY 11706

Production Date: 09/15/87 Pipe Diameter: 24 in. Cement Factor 750 #/cy
Forms Stripped 13.5 hrs. Actual Steel Area 0.10 sq.in.

Strength (psi)(7 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-4	Passed	29700
A-5	Passed	34200
A-7	Passed	35700
S-3	Passed	39700
S-4	Passed	-----
S-6	Passed	-----

Curing Conditions (First 7 Days)

Steam Temp. Range: - to - F.
Percent Rain: 50%
Humidity (%) Range: 65 to 80
Low Temp. Range: 53 to 64 avg. 58
High Temp. Range: 65 to 78 avg. 71

Strength (psi)(14 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-3	Passed	35700
A-8	Passed	37700
S-7	Passed	32700
S-8	Passed	35200

Curing Conditions (7-14 Days)

Percent Rain: 7%
Humidity (%) Range: 58 to 88
Low Temp. Range: 48 to 61 avg. 56
High Temp. Range: 64 to 84 avg. 77

Absorption: ASTM C497

*Sample #:	A-1	A-6	A-9	avg.	S-2	S-5	S-10	avg.
7 Day Core:	5.1	4.9	5.0	5.0	4.8	4.9	5.5	5.1
14 Day Core:	4.5	4.5	4.3	4.4	4.5	4.5	5.1	4.7

Freeze-Thaw Weight Loss (3% NaCl): NYSDOT 502-3P
25 Cycles - One Cycle per Day

*Sample #:	A-1	S-2
7 Day Core:	0.0	0.0
14 Day Core:	0.0	0.0

REMARKS:

* A designates air cure, S designates steam cure.

Strength Requirements - Class III:
0.01" Crack Load = 2700/Lin.Ft. x 8 Ft. Length, 21600
Ultimate = 4000/Lin.Ft. x 8 Ft. Length, 32000

Alternate Concrete Pipe Curing Test Results
N.Y.S.D.O.T. Materials Bureau

Company Name: Boccard Industries, Inc.
Location: 45 South 4th St., Bayshore, NY 11706

Production Date: 09/29/87 Pipe Diameter: 36 in. Cement Factor 750 #/cy
Forms Stripped 13.5 hrs. Actual Steel Area 0.18,0.14 sq.in.

Strength (psi)(7 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-3	Passed	86200
A-7	Passed	91700
A-10	Passed	93700
S-2	Passed	85200
S-3	Passed	97700
S-9	Passed	98200

Curing Conditions (First 7 Days)

Steam Temp. Range: - to - F.
Percent Rain: 29%
Humidity (%) Range: 41 to 100
Low Temp. Range: 42 to 54 avg. 46
High Temp. Range: 59 to 68 avg. 64

Strength (psi)(14 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-6	Passed	-----
S-7	Passed	-----

Curing Conditions (7-14 Days)

Percent Rain: 7%
Humidity (%) Range: 41 to 89
Low Temp. Range: 39 to 57 avg. 45
High Temp. Range: 53 to 66 avg. 57

Absorption: ASTM C497

*Sample #:	A-1	A-5	A-8	avg.	S-4	S-5	S-10	avg.
7 Day Core:	4.7	4.4	4.3	4.5	4.5	4.4	4.4	4.4
14 Day Core:	4.9	4.8	4.3	4.7	4.0	4.3	4.5	4.3

Freeze-Thaw Weight Loss (3% NaCl): NYSDOT 502-3P
25 Cycles - One Cycle per Day

*Sample #:	A-5	S-10
7 Day Core:	0.0	0.0
14 Day Core:	0.0	0.0

REMARKS:

* A designates air cure, S designates steam cure.

Strength Requirements - Class III:
0.01" Crack Load = 4050/Lin.Ft. x 8 Ft. Length, 32400
Ultimate = 6000/Lin.Ft. x 8 Ft. Length, 48000

Alternate Concrete Pipe Curing Test Results
N.Y.S.D.O.T. Materials Bureau

Company Name: Bundy Concrete Products, Inc.

Location: 548 Snell St., Watertown, NY 13601

Production Date: 09/28/87 Pipe Diameter: 12 in. Cement Factor 575 #/cy
Forms Stripped 17.5 hrs. Actual Steel Area 0.08 sq.in.

Strength (psi)(7 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-3	Passed	-----
A-6	Passed	47500
A-10	Passed	-----
S-3	Passed	-----
S-6	Passed	43000
S-10	Passed	-----

Curing Conditions (First 7 Days)

Steam Temp. Range: 85 to 141 F.
Percent Rain: 14%
Humidity (%) Range: 55 to 93
Low Temp. Range: 34 to 60 avg. 49
High Temp. Range: 50 to 78 avg. 64

Strength (psi)(14 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-1	Passed	52500
S-1	Passed	46500

Curing Conditions (7-14 Days)

Percent Rain: 29%
Humidity (%) Range: 49 to 90
Low Temp. Range: 34 to 52 avg. 42
High Temp. Range: 47 to 72 avg. 58

Absorption: ASTM C497

*Sample #:	A-2	A-5	A-9	avg.	S-2	S-5	S-9	avg.
7 Day Core:	5.3	4.7	5.5	5.2	4.6	5.0	5.8	5.1
14 Day Core:	5.6	5.8	5.3	5.7	5.3	5.4	5.9	5.5

Freeze-Thaw Weight Loss (3% NaCl): NYSDOT 502-3P
25 Cycles - One Cycle per Day

*Sample #:	A-9	S-9
7 Day Core:	0.0	0.0
14 Day Core:	0.0	0.0

REMARKS:

* A designates air cure, S designates steam cure.

Strength Requirements - Class III:
0.01" Crack Load = 1350/Lin.Ft. x 7.5 Ft. Length, 10125
Ultimate = 2000/Lin.Ft. x 7.5 Ft. Length, 15000

Alternate Concrete Pipe Curing Test Results
N.Y.S.D.O.T. Materials Bureau

Company Name: L. S. Lee & Son

Location: Oaks Corners, NY 14518

Production Date: 10/20/87 Pipe Diameter: 12 in. Cement Factor 800 #/cy
Forms Stripped 21.5 hrs. Actual Steel Area 0.10 sq.in.

Strength (psi)(7 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-1	Passed	-----
A-6	Passed	-----
A-9	Passed	41000
S-1	Passed	-----
S-6	Passed	-----
S-9	Passed	36250

Curing Conditions (First 7 Days)

Steam Temp. Range: 108 to 124 F.
Percent Rain: 33%
Humidity (%) Range: 47 to 100
Low Temp. Range: 25 to 34 avg. 31
High Temp. Range: 42 to 56 avg. 50

Strength (psi)(14 Day): ASTM C497

*Sample #	Load 0.01"	Ultimate
A-10	Passed	41000
S-10	Passed	48000

Curing Conditions (7-14 Days)

Percent Rain: 29%
Humidity (%) Range: 67 to 92
Low Temp. Range: 30 to 42 avg. 36
High Temp. Range: 44 to 60 avg. 52

Absorption: ASTM C497

*Sample #:	A-2	A-5	A-8	avg.	S-2	S-5	S-8	avg.
7 Day Core:	6.9	7.1	6.6	6.9	6.4	6.5	6.7	6.5
14 Day Core:	6.6	6.6	5.6	6.3	6.1	6.2	5.8	6.0

Freeze-Thaw Weight Loss (3% NaCl): NYSDOT 502-3P
25 Cycles - One Cycle per Day

*Sample #:	A-4	S-4
7 Day Core:	0.0	0.0
14 Day Core:	0.0	0.0

REMARKS:

* A designates air cure, S designates steam cure

Strength Requirements - Class III:
0.01" Crack Load = 1350/Lin.Ft. x 6 Ft. Length, 8100
Ultimate = 2000/Lin.Ft. x 6 Ft.Length, 12000

RESULTS

Absorption Tests

As can be seen from the preceding summary forms, all the core samples passed the absorption test, the values obtained being less than the 8% by weight limit required by the Standard Specifications. The values also show a minimal difference in absorption between air cured and steam cured core samples, which indicates that the method of cure, under the given conditions, had no significant effect on test results.

Freeze-Thaw Tests

The preceding summary forms also show that, under the given conditions, the method of cure had no influence on freeze-thaw performance, no damage (loss) having been recorded in any of the core samples.

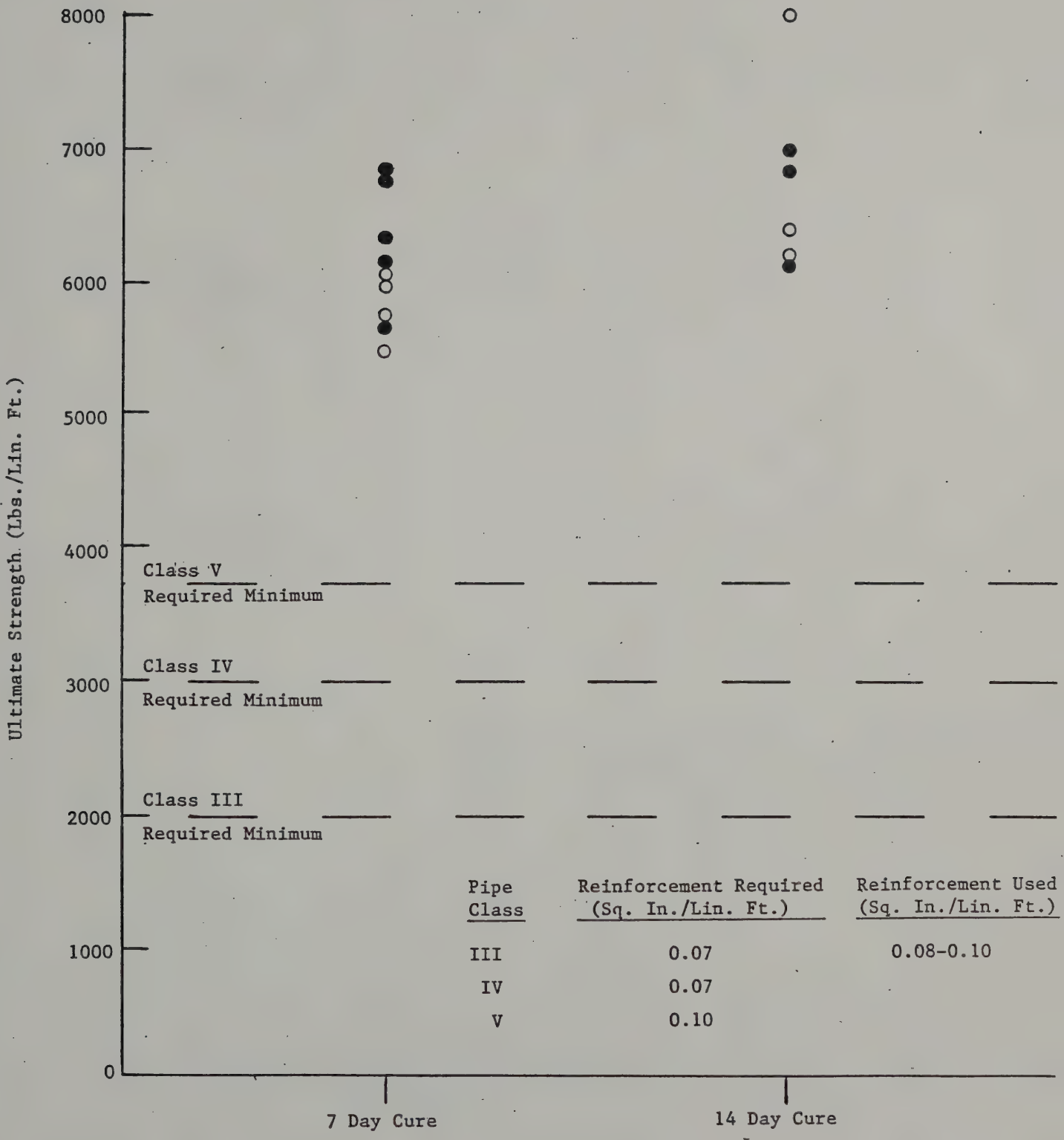
Strength Tests

Results of three-edge bearing tests show that all the air cured and steam cured sample pipe tested, were capable of surpassing the specified minimum load requirement prior to the appearance of a 0.01" crack at 7 days. (Excerpts from Materials Method I, Quality Assurance Procedure For Concrete Pipe Items, which describe the three edge bearing test and lists the test load requirements for Class III, IV and V RCP are available from the Materials Bureau upon request.) The specified minimum load for ultimate strength was also surpassed by all the sample pipe except for one air cured pipe.

Examination of the test data reveals no correlation between the results and curing method. However, there is correlation between the results and the amount of reinforcement used in the production of the various sized pipe. This is demonstrated in the following graphs where the ultimate strength test results for each sized sample pipe are plotted. Each graph includes the Class III, IV and V minimum ultimate load requirements for their respective sizes. Also included on the graphs, is a table containing the minimum amount of reinforcement required for each pipe class and the actual amount used when the sample pipe were made.

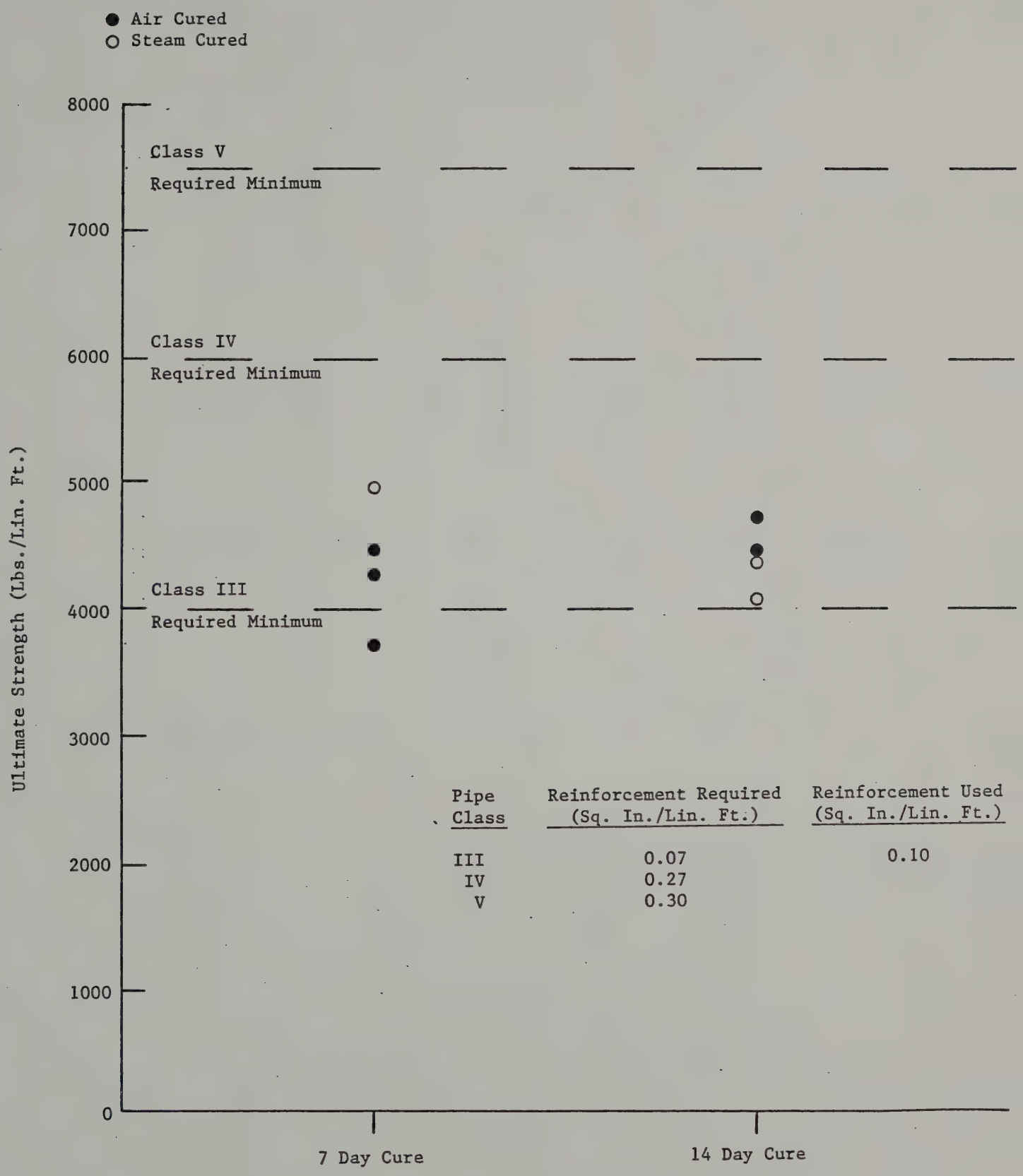
TWELVE INCH DIAMETER RCP -
SEVEN DAY AND FOURTEEN DAY ULTIMATE STRENGTHS

● Air Cured
○ Steam Cured



Pipe Class	Reinforcement Required (Sq. In./Lin. Ft.)	Reinforcement Used (Sq. In./Lin. Ft.)
III	0.07	0.08-0.10
IV	0.07	
V	0.10	

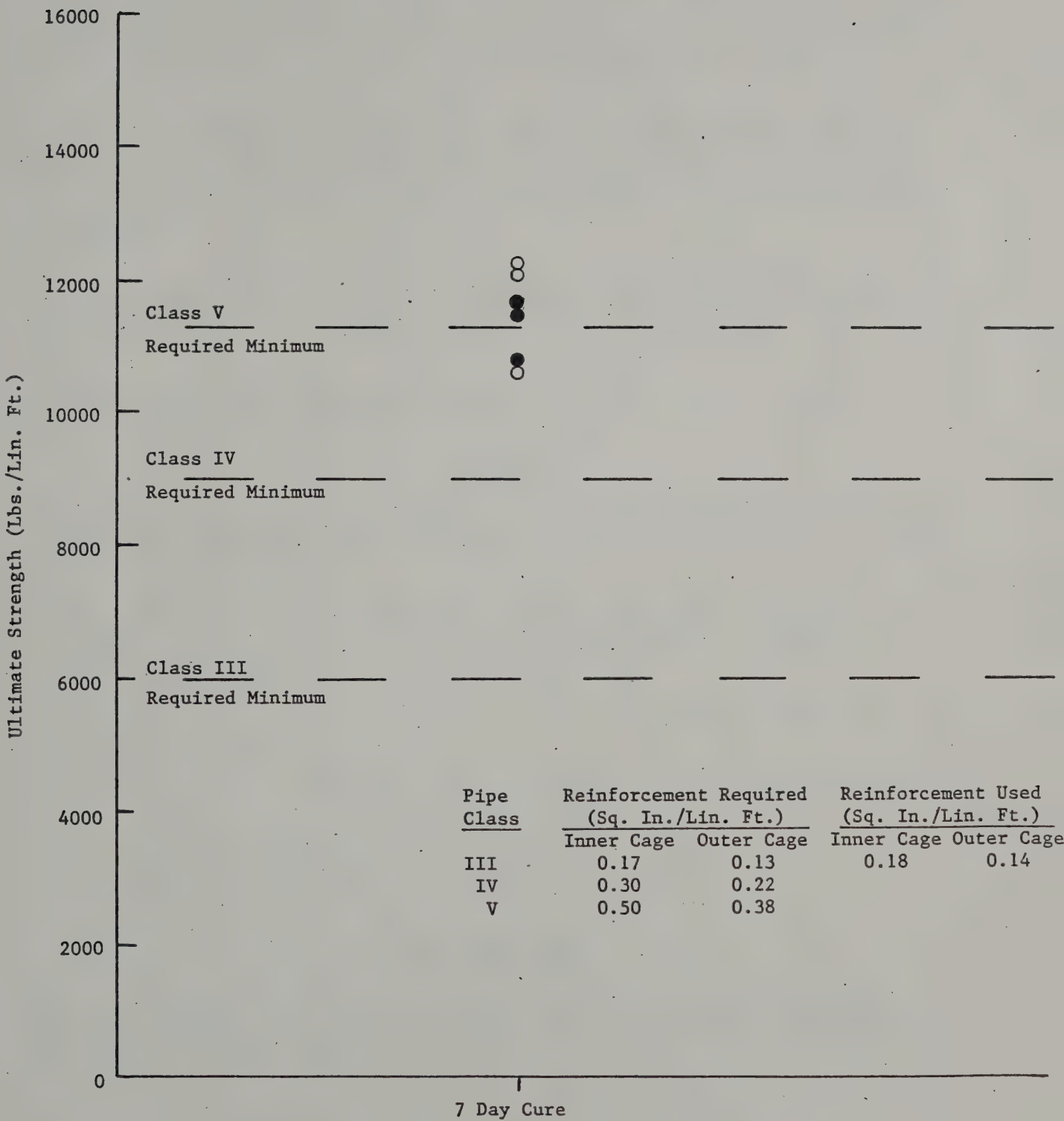
TWENTY-FOUR INCH DIAMETER RCP -
SEVEN DAY AND FOURTEEN DAY ULTIMATE STRENGTHS



Pipe Class	Reinforcement Required (Sq. In./Lin. Ft.)	Reinforcement Used (Sq. In./Lin. Ft.)
III	0.07	0.10
IV	0.27	
V	0.30	

THIRTY-SIX INCH DIAMETER RCP -
SEVEN DAY ULTIMATE STRENGTHS

● Air Cured
○ Steam Cured



Pipe Class	Reinforcement Required (Sq. In./Lin. Ft.)		Reinforcement Used (Sq. In./Lin. Ft.)	
	Inner Cage	Outer Cage	Inner Cage	Outer Cage
III	0.17	0.13	0.18	0.14
IV	0.30	0.22		
V	0.50	0.38		

As can be seen from the graph containing the test results of the 12 inch diameter sample pipe, the amount of reinforcement used was comparable to that required for Class V pipe. The difference between the amount used and the amount required is reflected in the test results which easily exceed the minimum ultimate strength requirements for Class V pipe. Even though it is more costly, RCP producers routinely make 12 inch diameter pipe to Class V standards. As a result it meets the requirements, and can be sold for Class III and IV as well. It also eliminates the need to keep various sized rolls of reinforcement on hand. Consequently, the additional cost of reinforcement is offset.

On the graph containing the test results of the 24 inch diameter sample pipe, the amount of reinforcement used was slightly more than that required for Class III pipe. Test results indicate this, in that they fall between the minimum ultimate strength requirements for Class III and IV pipe (except for one air cured sample pipe which failed to meet the Class III ultimate strength requirement).

On the graph containing the test results of 36 inch diameter sample pipe, the amount of reinforcement used was also more than that required for Class III pipe. In this case, test results exceeded the minimum requirement for Class IV pipe.

As previously stated, there was no indication that the test results were influenced by the method of cure.

CONCLUSIONS

The following conclusions can be considered valid for RCP produced under environmental conditions that fall within the parameters experienced during the curing periods of this study.

(1) The majority of air cured RCP demonstrated higher absorption characteristics than their steam cured counterparts. However, the difference was minimal and considered insignificant in comparison to the minimum absorption allowed by NYS specifications.

(2) No difference in freeze-thaw characteristics was found between air cured and steam cured RCP.

(3) No difference in strength was found between air cured and steam cured RCP.

(4) Air cured pipe showed acceptable strengths at 7 days.

(5) The ability to strip rings at 12 hours is not proven.

RECOMMENDATIONS

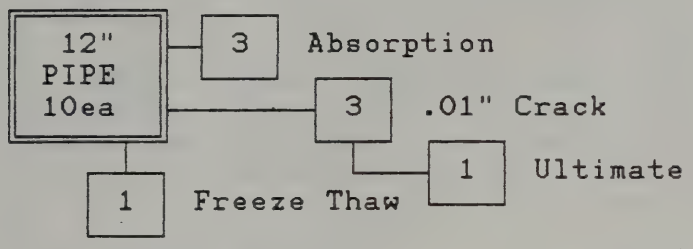
Based on the results obtained thus far, it is recommended that this study be continued to obtain test results for machine made and wet cast RCP produced in the Summer (hot weather production).

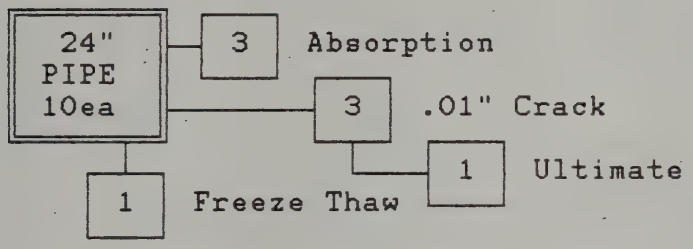
APPENDIX

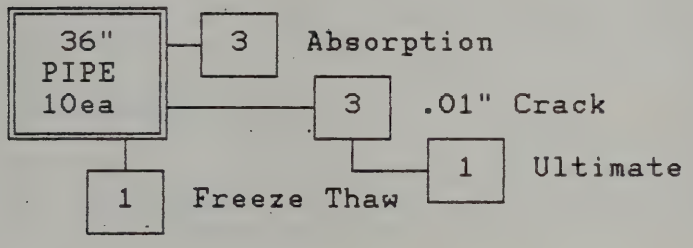
NYSDOT/NYSCPA Alternate Curing Study For Concrete Pipe

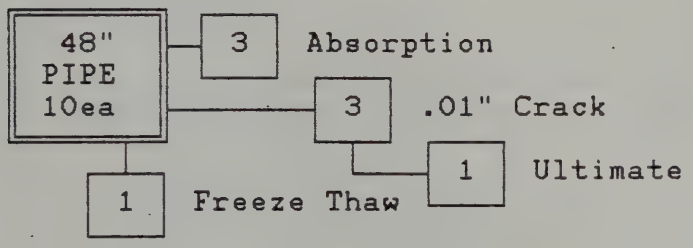
NYSDOT/NYSCPA
ALTERNATE CURING STUDY

STANDARD CURING METHOD

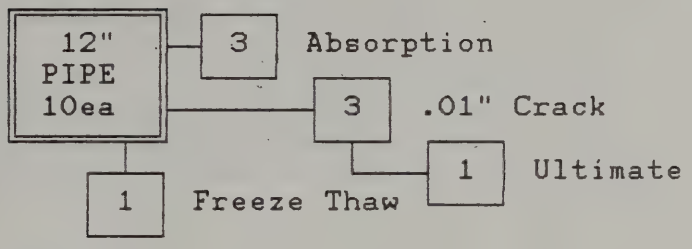


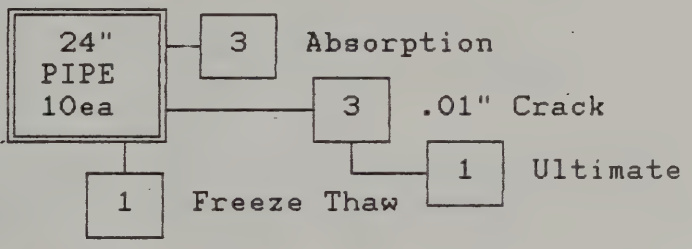


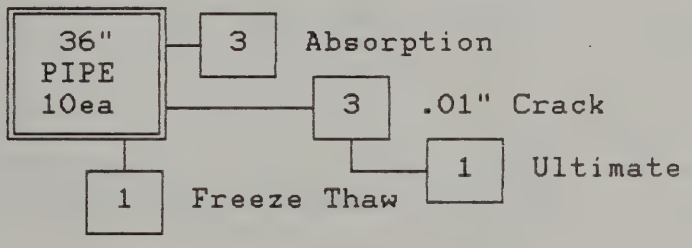


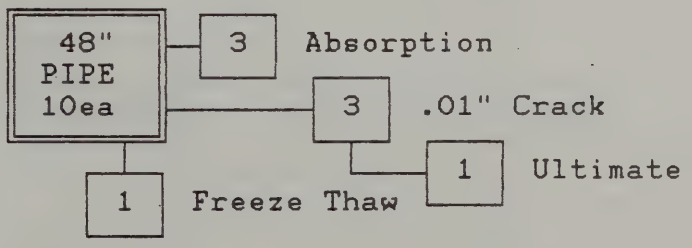


MODIFIED CURING METHOD









NOTES:

STANDARD CURING METHOD:
Steam for 12 hours as per 706-02, Section 3.C-1

MODIFIED CURING METHOD:
Machine Made - Pipe set in kiln, forms removed but no steam applied. Rings removed after 16 hours (min.)

Wet Cast - Cover over top of form (or curing compound with fugitive dye) applied immediately. Cover, forms and rings to be removed after 16 hours (min.).

3/17/87

NYSDOT/NYSCPA
ALTERNATE CURING STUDY
FOR CONCRETE PIPE

GENERAL

A modified curing method will be compared to the standard 12 hour steam cure. Each of three manufacturers will produce pipe with Lots of varying diameter pipe, machine made and cast.

Pipe shall be manufactured in standard 8', 7'-6" or 6' (for larger diameter) lengths. The pipe sections will be marked so as to preserve the identity of each piece. The modified curing method will be permitted only when temperatures remain at 50°F or above.

A. CURING METHODS

See attachment. A modified and a standard procedure will be used.

B. PIPE SIZE & CLASS

See attachment. Pipe sizes of 12", 24", 36" and 48"(or greater) shall be used for this study. Pipe shall be Class III and shall be the same for all manufacturers.

The 12", 24" and 36" sizes shall be machine made and the 48"(or greater) size shall be cast.

C. QUANTITIES

For each diameter pipe and method of curing, each of the three manufacturers will manufacture a Lot of ten (10) sections. See attachment.

D. EQUIPMENT

Humidity gauges and thermometers shall be provided by the manufacturer to measure environmental conditions in the enclosure used for curing.

E. TESTING

See attachment. All testing will be performed immediately at the end of fourteen (14) days of curing or as approved by the Director, Materials Bureau.

F. DOCUMENTATION

All manufacture, curing and testing will be conducted in the presence of a representative of the Department.

G. ACCEPTANCE

Only pipe manufactured in accordance with the standard curing method will be considered for acceptance.

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